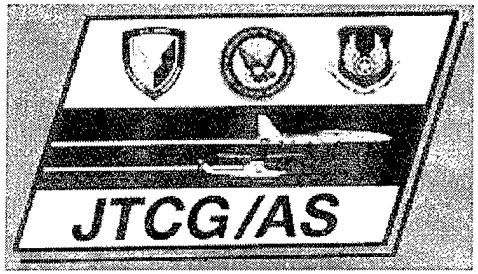


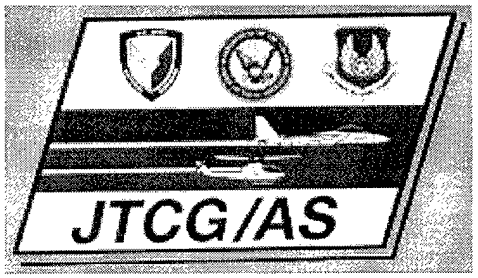

# Flight Systems' Integration Impact On Aircraft Vulnerability

**Bruce Clough**

**JTCG/AS Vulnerability Reduction Subgroup,**
**Flight Systems Committee**

**John Perdzock**
**Flight Control Division**
**Air Force Research Laboratory**

**Technical Content Meter:**
**Low** **High**




# Purpose & Overview

- **Sensitize Survivability Personnel To Technological Advances In Flight Systems**
  - **What are the new technologies?**
  - **How do they impact vehicle vulnerability?**
  - **Do we need to "worry"?**
  - **…if so, what should we do?**
- **What will be covered**
  - **Short Review Of Each Technology**
  - **Possible Vulnerability Impacts**
  - **Where To Go From Here**

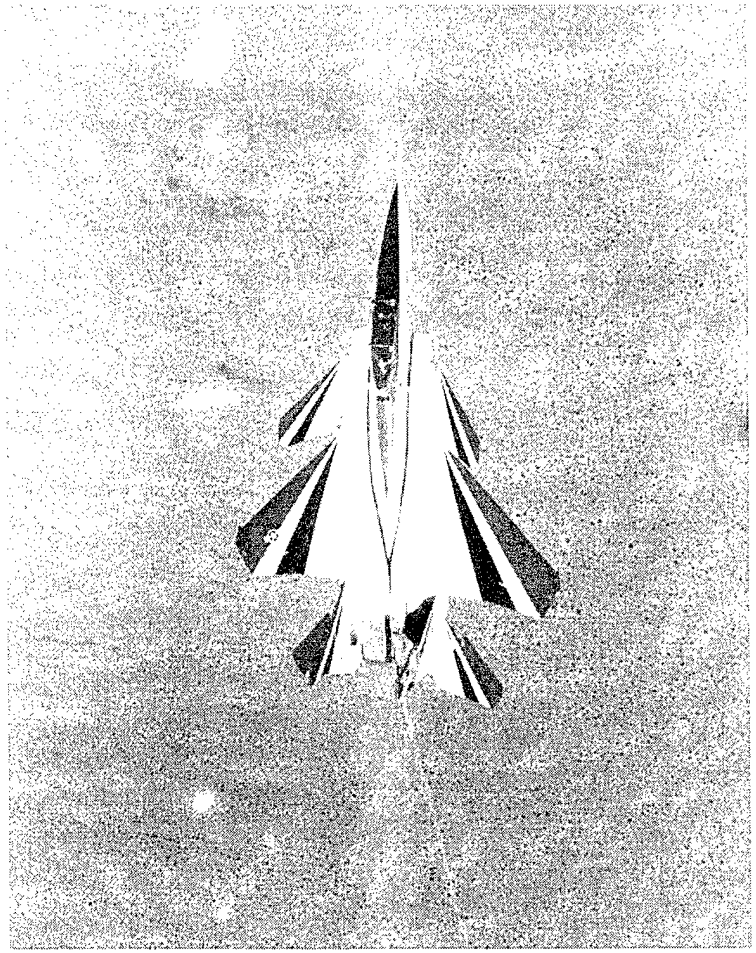

# Technology Areas Covered

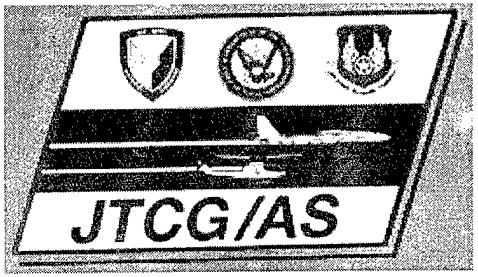
- Integrated Flight/Propulsion Control
- Tailless Aircraft
- Integrated Flight/Structure Control
- More Electric Aircraft
- Integrated Thermal/Secondary Power
- Prognostics & Health Management
- Vehicle Management Systems

# Integrated Flight/Propulsion Control

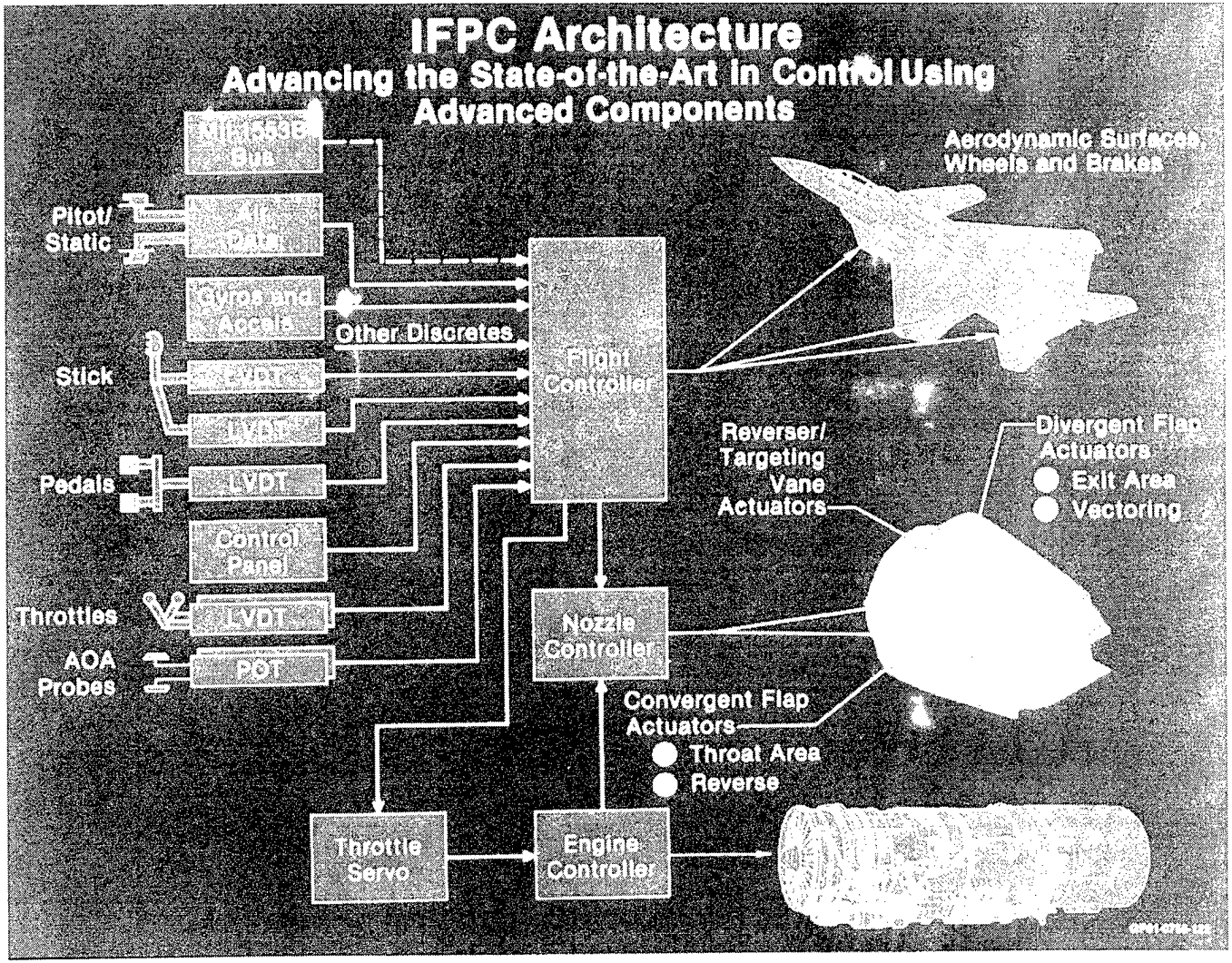
- IFPC Integrates Separate Flight and Engine Control Functions
- IFPC Empowers Greater Aircraft Performance
  - Enhanced Maneuvering
  - Reduced Fuel Consumption
- Plenty Of IFPC System Experience
  - STOL/Maneuver Technology Demonstrator
  - NASA/HARV
  - MATV F-16
  - X-31, et al

...oh, and the F-22...



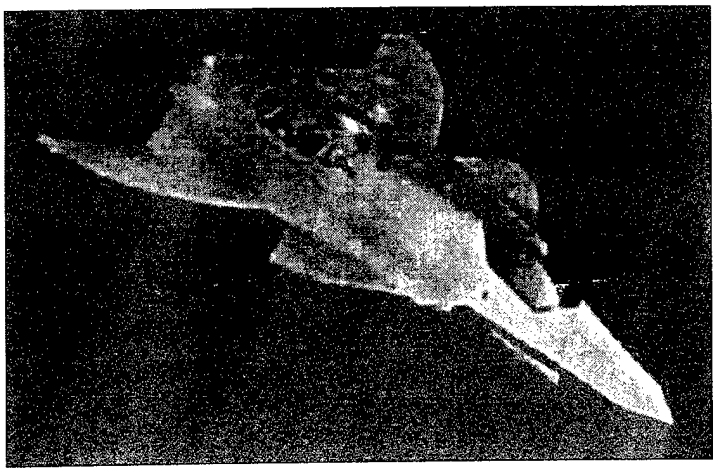


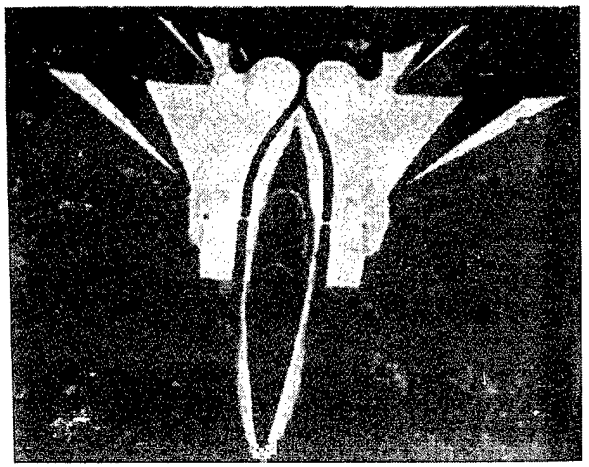

# Integrated Flight/Propulsion Control



# Tailless Fighter Aircraft

***Highly maneuverable*** **tactical aircraft…**





**...with reduced or *no vertical tail***

**Benefits:**

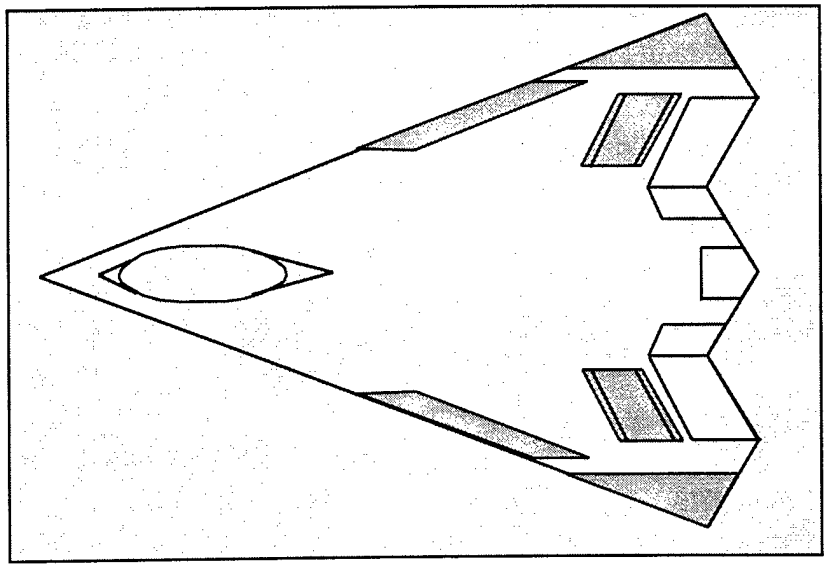
- **Lower observability**
- **Reduced weight**

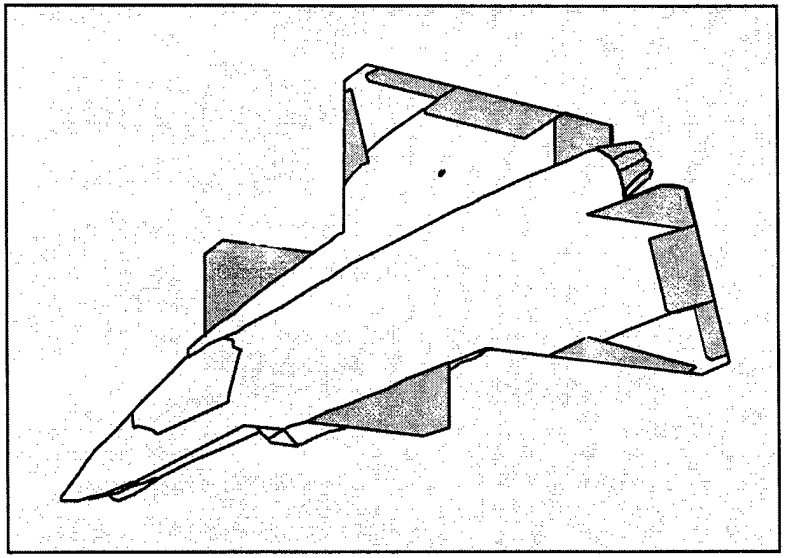
**Challenges:**

- **Reduced directional stability**
- **Reduced directional control power**
- **Maintain current maneuverability**

# Tailless Fighter Aircraft

**Flight control system restores directional control power...**





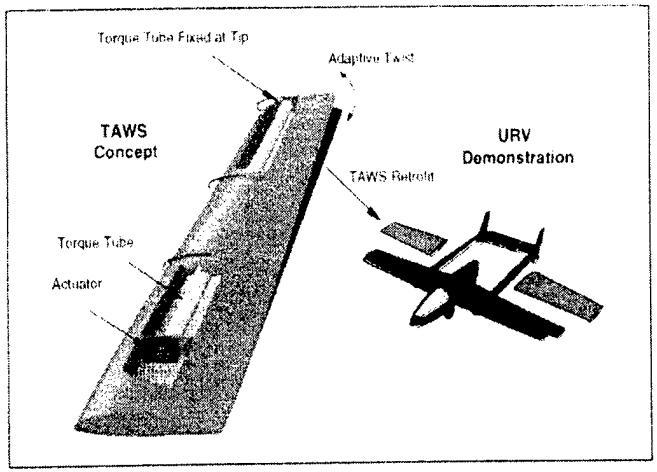
**...using innovative control effector suite and advanced control theory**


# Integrated Flight/Structure Control

- IFSC is the active, real-time controlling of aircraft structure to:
  - Eliminate Structural Weight
  - Increase Aircraft Agility
- Current Wing Weight Driven By Torsional Stiffness, Not Strength
- Using Active Control Allows:
  - Structural Load Control (Maneuver, Gust)
  - Structural Shape Control (Twist, Camber)
  - Structural Mode Control (Vibration, Flutter)

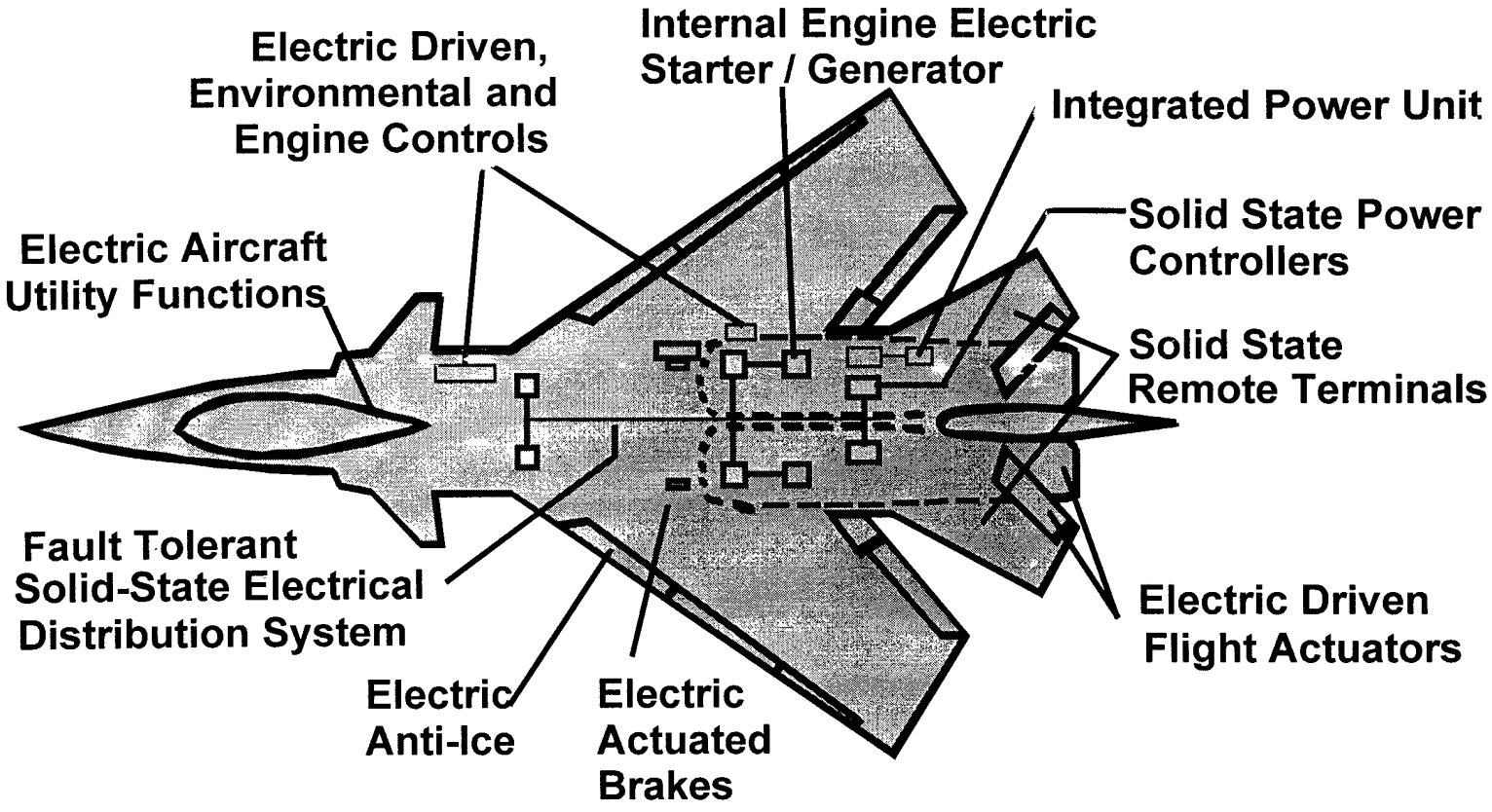

# Integrated Flight/Structure Control: Ongoing Programs

- **Active Aeroelastic Wing**
  - **Joint AF/NASA Program**
  - **Eliminate Structural Weight**
  - **Using Modified F-18A**
  - **Flight Test Concept FY00**


- **Twist Adaptive Wing**
  - **Integral Torque Tube**
  - **No Seams, Low RCS**
  - **Flight Tests On UAV FY98**

# More Electric Aircraft Technology



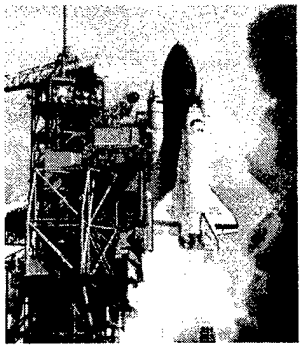

**Goal: Replace ALL Aircraft Secondary Power With One Type: ELECTRIC**

# MEA Benefits

## Maintainability
- Reduced Logistics Tail
- Eliminates CHS Support Equipment
- Improved MTBF
- Improved MTTR (LRU)

## Design Payoffs
- Systems Level Weight Savings
- Improved System Survivability
- Reduced Vulnerability
- Increased Subsystem Design Freedom

## O&S
- Increased Aircraft Sortie Rate
- Improved Life Cycle Costs
- Improved Mobility/Deployment



## Performance
- Less Secondary Power Extraction
- Improved Thermal Management (Power on Demand)

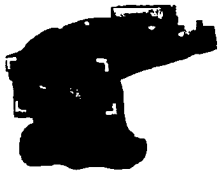
JTCG/AS

# MEA Reduces Cost Of Global Power Projection

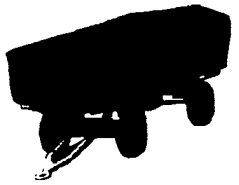
- HYDRAULIC FLUIDS, LUBRICANTS, ASSOCIATED CLEANING SOLUTIONS
- FLIGHT LINE BATTERY SUPPORT SHOP
- 60 OF 458 MAINTENANCE MANPOWER (F-16)
- 3.5 OF 16 C-141 SORTIES (F-16)

**SAVINGS IN $B's WITH IMPROVED WARFIGHTING**

## . . . BY ELIMINATING:



Electric Generator



Hydrazine Servicing Cart

Hydraulic Servicing Cart

High Pressure Air Cart

Air Conditioner

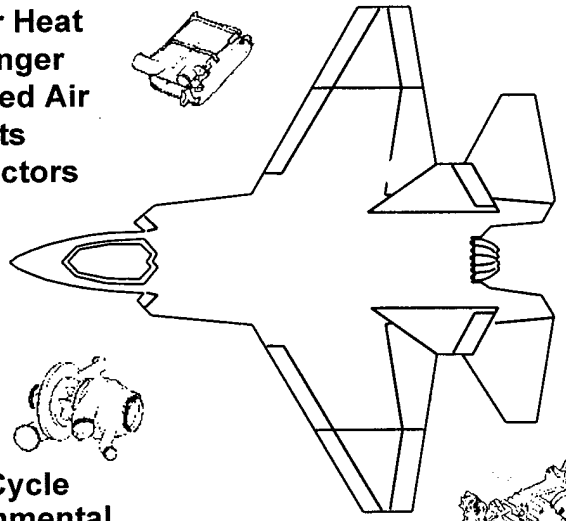
Hydraulic Mule

545

SC95/035

# Thermal/Secondary Power

## Conventional



Ram Air Heat Exchanger with Bleed Air Ducts and Ejectors

Emergency Power Unit (EPU)

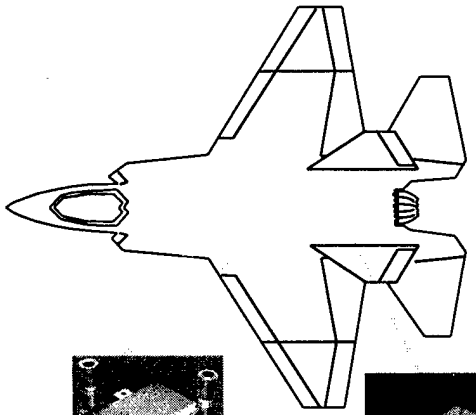
Auxiliary Power Unit (APU)

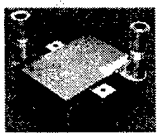
Air Cycle Environmental Control System (ECS)

Vapor Cycle ECS

Airframe Mounted Accessory Drive (AMAD)

## Integrated





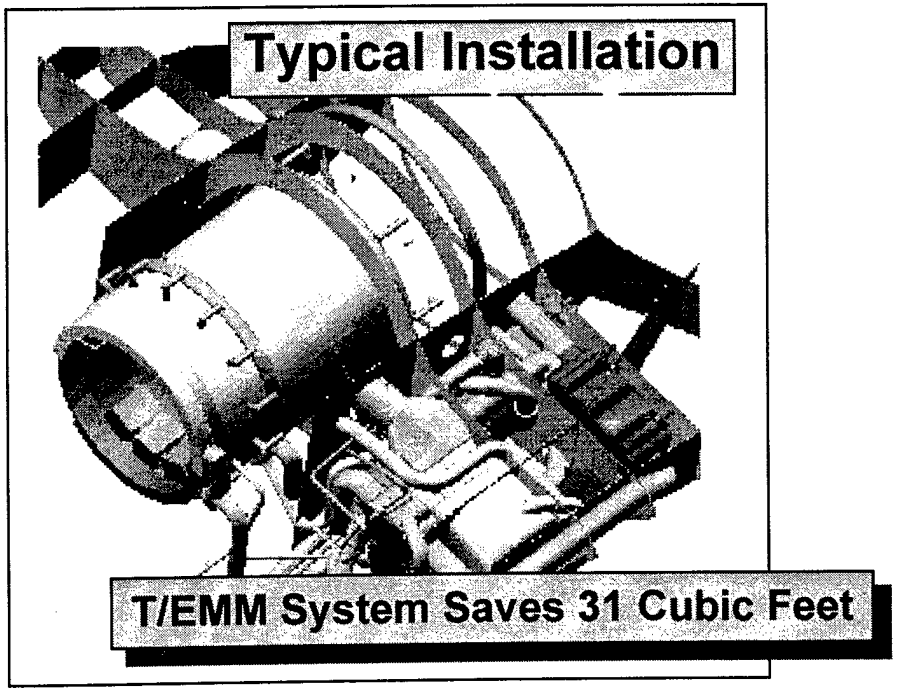
High Temp Hx in Engine Fan Duct

Thermal /Energy Management Module (T/EMM)

**Improved Efficiency and Lower Equipment Count Enables Smaller, Lighter and Lower Cost Aircraft**

# Integrate Thermal/Secondary Power Benefits

JTCG/AS




**Provides Electrical Power and Cooling for Required Aircraft Subsystems Functions :**

- Deck Edge Maintenance
- Stand Alone Start
- Ground Maintenance
- Main Engine Start
- Normal Flight
- Normal Flight with Electric Power
- Emergency Power - Stored Air
- Emergency Power - Ambient Air

- 3%- 5% Reduction in Procurement Cost
- 3%- 4% Reduction in LCC
- Up To 5.5% Reduction in TOGW or
- Up To 20% Improvement in Range ... Not Resized

# Integrated Diagnostics/ Prognostics

JTCG/AS

## DIAGNOSTICS DESIGN

DESIGN

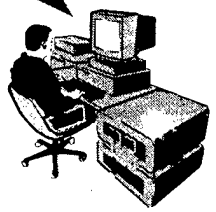
DIAGNOSTICS TEST BENCH

DEMOS

ANALYSIS

## SUBSYSTEM DIAGNOSTICS

PROPULSION
SENSORS
ELECTROSTATIC
ACOUSTICAL FOD
LIFE ALGORITHMS
J/IST DIAGNOSTICS
STRUCTURAL HEALTH MONITORING

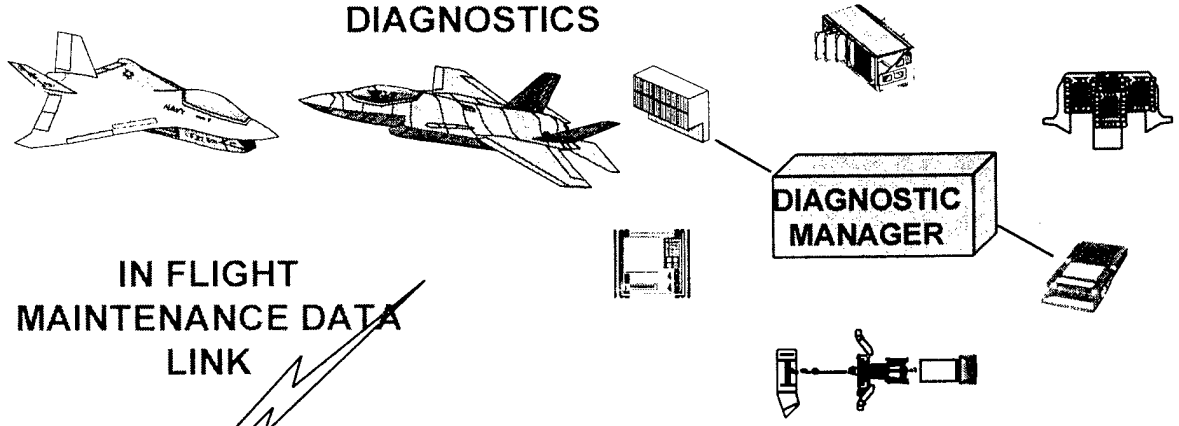


STIMULATES RESPONSE

AUTONOMIC SUPPORT

IN FLIGHT MAINTENANCE DATA LINK

ON BOARD DIAGNOSTICS




SMART TECHNICIAN / AIRCRAFT INTERFACE

MAINTENANCE SCHEDULING
FAULT ISOLATION
FLIGHT SCHEDULING
HEALTH TRENDING
PARTS ORDERING
UPDATE RECORDS

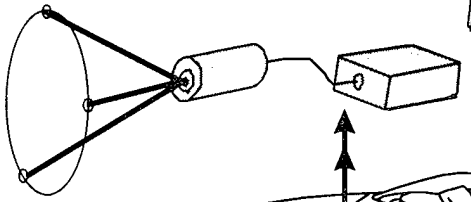

# Integrated Diagnostics/ Prognostics

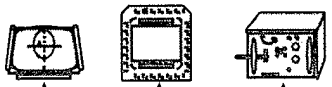
| Diagnostic | Existing | Near Future |
|---|---|---|
| • Fault Prediction (Prognostics) | • Fixed estimate of life based on statistical projections | • Real-time estimate of remaining life assessment by tail # |
| • Fault Detection | • On-board BIT plus performance evaluation | • Real-time correlated BIT and data capture |
| • Fault Isolation | • Generally post flight with some fault tolerant redundancy<br>• Predesigned FI manuals | • Interactive Portable Maintenance Aids (PMAs) & data transmsn for 2nd level FI |
| • Fault Analysis | • Paper instructions & gnd support equip<br>• Remote engr function | • Remote data analysis using flight data downlink |
| • Fault Correction | • ECP process | • Real-time process improvement using on-line databases, rapid prototyping and flexible software techniques |

# Vehicle Management System

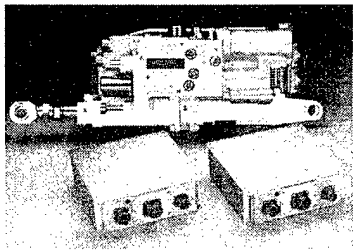

Mission Avionics

Air Data System





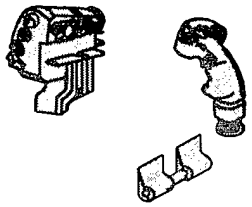
Avionics Bus



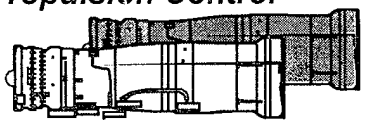
Power-By-Wire (PBW) Actuation

Utility Subsystems

Pilot Vehicle Interface

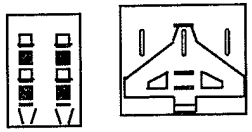


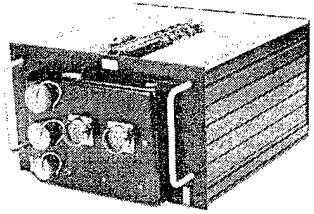
Propulsion Control

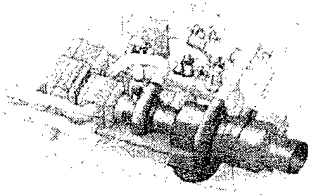


Vehicle Management Computers

Flight Critical Displays

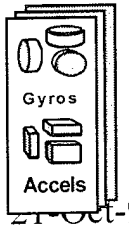


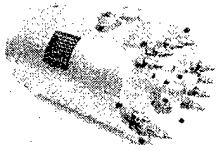




T/EMM

IMU



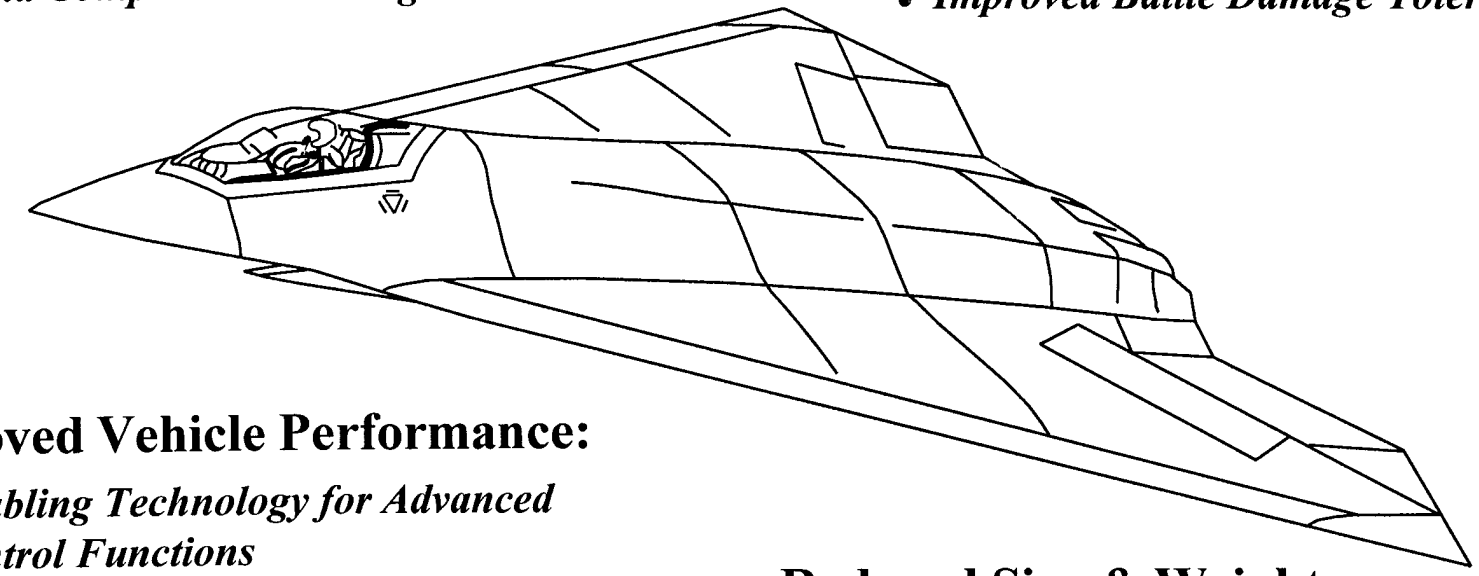



MEA Power Distribution System

VMS Data Bus

# VMS Benefits

- **Improved Life Cycle Cost:**
  - *Use of Commercial Technologies and Practices*
  - *Reduced Hardware Coun*
  - *Improved Design Tools and Techniques*
  - *Rapid Comprehensive Integrated V&V*
- **Improved Vehicle Survivability:**
  - *Improved EMI Tolerance*
  - *Increased Fault Tolerance*
  - *Improved Reliability*
  - *Improved Battle Damage Tolerance*

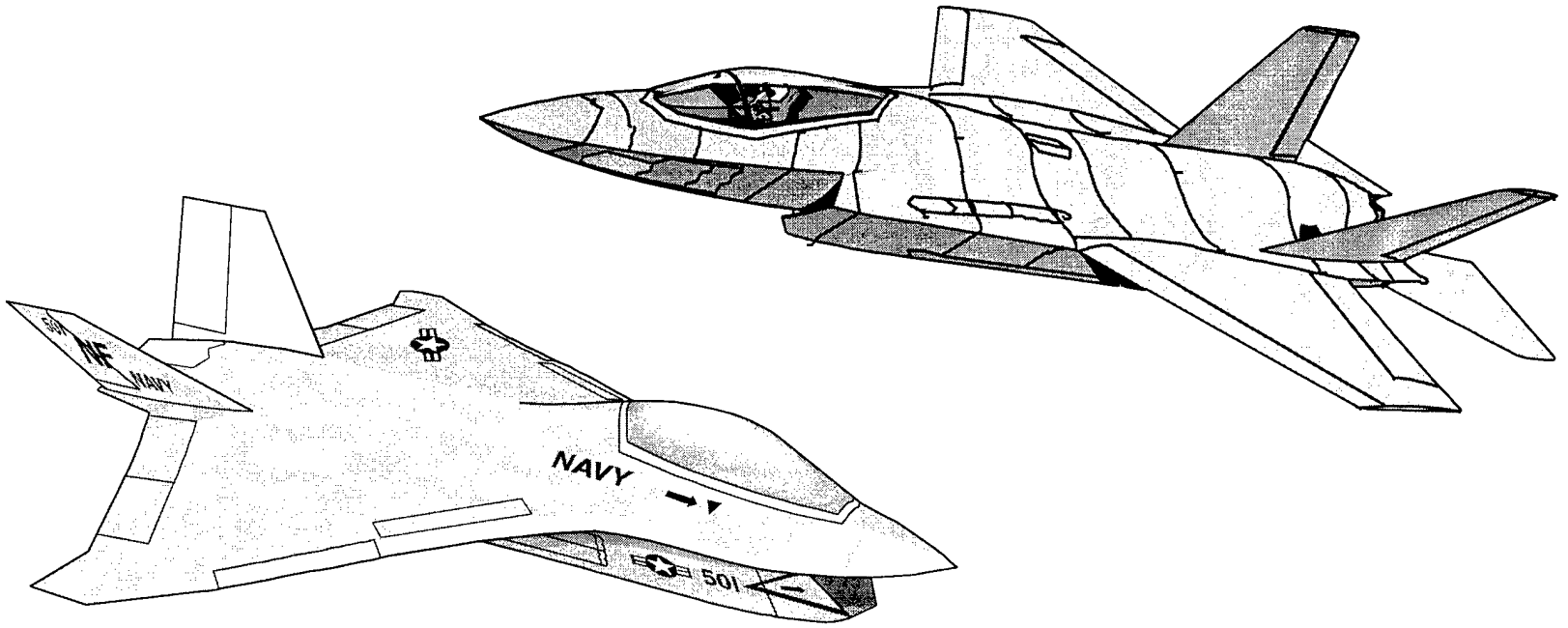


- **Improved Vehicle Performance:**
  - *Enabling Technology for Advanced Control Functions*
  - *Scaleable Open Architecture for Growth Potential*
  - *Modular Upgrades to Avo d Obsolescence*
- **Reduced Size & Weight:**
  - *Reduced Cabling Weight*
  - *Reduced Parts Count*

551

JTCG/AS

# Pipe Dreams? Heads Up, Here Comes JSF!




***Pound For Pound The Most "Integrated" Weapon System Built To Date!***


# Integration Survivability Impacts

## PROS

- Smaller Cross Sections
- Less Waste Heat
- Reduced Computer Counts
- Reduced Wiring
- Better Damage identification
- Better Prognostics & Health Management
- Less Flammable Fluids


## CONS

- Individual components can be critical for multiple systems
- Unknown failure modes
- Systems Becoming Critical That Weren't In The Past
- Mix of Critical & Non-Critical Software Muddies Reaction To Failures
- Allows Reduced Strength In Other Systems (such as structures)


# That's Great, But What Do We Do?

**First**

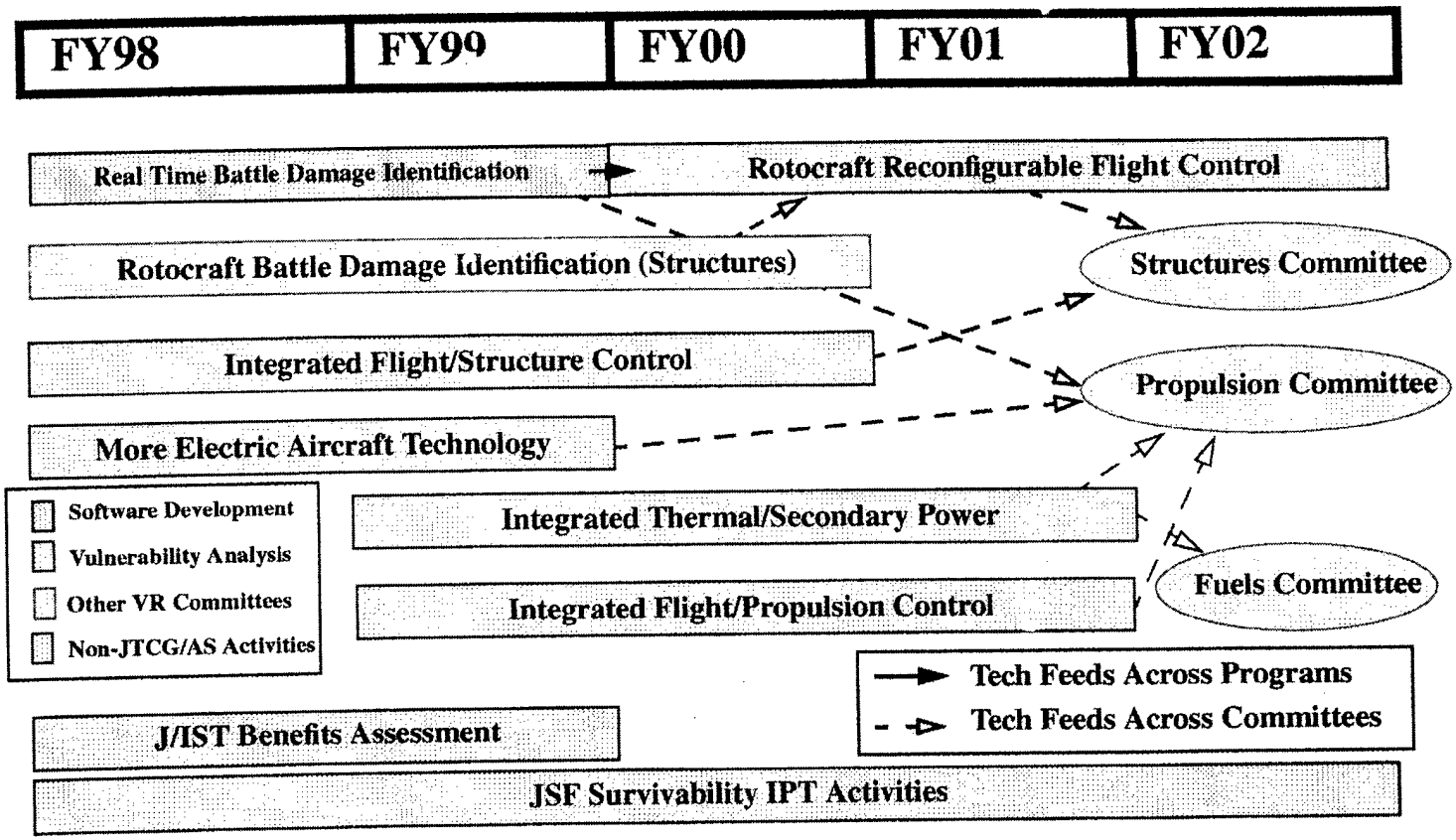
[redacted]

**Then**

[redacted]

# Roadmap To Answers

*JTCG/AS Flight Systems Committee Programs*




# Conclusions

- **Performance Increase, Cost Reduction, Driving Integration Of Aircraft Systems**
- **Decreased Survivability Due To Increased Vulnerability, i.e., Single-Point Failures?**
- **Increased Survivability Due To Decreased Susceptability, i.e., Increased Performance And Reduced Observability?**
- **Studies Underway, Or Planned, Assessing Vulnerability Impacts Of Integration And Possible Risk Reduction**

***Community Is Stepping Up To The Challenges Posed By Systems Integration***